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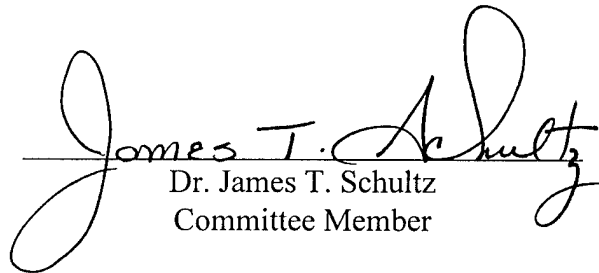
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This Graduate Research Project was prepared under the direction of the candidate's Research Committee Member, Dr. James T. Schultz, Associate Professor, Extended Campus, and the candidate's Research Committee Chair, Dr. Marian C. Schultz, Associate Professor, University of West Florida, and has been approved by the Project Review Committee. It was submitted to the Extended Campus in partial fulfillment of the requirements for the degree of Master of Aeronautical Science

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The purpose of this research was to ascertain whether a significantly disproportionate number of general aviation fatal aircraft accidents occur at night. The percentage of all fatal accidents that occur at night, collected over a ten year span, were compared to the percentage of hours flown at night. Research determined that there is a significantly disproportionate number of night fatal accidents. An additional area examined was whether a significantly larger proportion of night (versus day) fatal accidents had *inflight encounter with weather* as the first occurrence (the first of any number of occurrences or events which contribute to an accident). The study resolved that a significantly higher percentage of night accidents have inflight encounter with weather as the first occurrence.

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CHAPTER I

INTRODUCTION

The Statement of the Problem

The problem to be researched is whether a significantly disproportionate number of general aviation (GA) fatal accidents occur at night. A secondary problem to be resolved is whether a significantly higher percentage of night fatal accidents involve *inflight encounter with weather* as the first occurrence (as compared to day fatal accidents). The first occurrence is the first of any number of occurrences or events which contribute to an accident.

An additional purpose of this study is to research and report on the unique factors associated with flying GA aircraft at night. Research was also conducted to identify if non-instrument rated pilots are more at risk when night flying than instrument rated pilots.

Background

Until approximately 1920, night flying was generally thought to be impractical and was used primarily in emergency situations. The reservation about night flying is understandable since, in those early days, simply completing a daylight flight without a mishap was quite an accomplishment.

The federal government did much to foster night flight during the 1920s when a transcontinental airway system was established using an airway beacon network

consisting of blinkers and beacons equally spaced three miles apart. The early aviators were then able to determine their location and the distance to their next checkpoint with reasonable accuracy. With the advent of this new navigational development coupled with basic runway lighting and dramatically improved aircraft reliability, in less than one decade, pilot fatalities per mile decreased by a factor of more than 20 times. Still, much development was needed to increase the practicality of nighttime piloting activities during aviation's early years. (Haines & Flatau, 1992, p. 3)

Since that time, significant technological advancements, particularly in the area of aircraft instrumentation, have made night flying commonplace. Most GA pilots today would agree that, on average, there are additional risks associated with night flying as opposed to day flying under similar conditions (weather, aircraft condition, and pilot proficiency, for example). The degree to which there is an increased risk and what should be done to mitigate that risk, however, is often a subject of controversy.

The advantages and utility of night flying are fairly evident. The air is generally much smoother than during the day and, depending on the geographic area, there is usually much less traffic. The airplane performs better in the cool night air. With good visibility, cities, airports, highways, and other lighted landmarks can be seen at far greater distances than during daylight. "The beauty of a full moon shining down on a layer of clouds is a spectacular sight for any pilot who views it from the cockpit of an airplane flying high above that layer of clouds" (Haines & Flatau, 1992, p. 6). Indeed, night flying can be a wonderful and exhilarating experience. It is also very easy for experienced pilots to become quite relaxed in the cockpit at night.

The exposure to night operations that a student pilot, aspiring to become a private pilot, receives is relatively limited in most cases. Yet the vast majority of private pilots enjoy the privilege of night flying. Provided the private pilot has no limitations on his or her certificate, he or she may also carry passengers at night, so long as, within the preceding 90 days, that pilot has made at least three takeoffs and landings to a full stop at night.

Author's Work Setting and Role

The author holds the USAF Aeronautical Rating of Instructor Weapons Systems Officer, with experience in the RF-4C and most recently qualified as an instructor in the F-15E. Regarding civilian flight experience, he, like many non-instrument rated private pilots, flies periodically, but not consistently throughout the year. Because of the cost associated with civilian flying, he flies primarily when there is a need or a special opportunity to do so. As to night flying, he must usually "get current" before carrying any passengers on a flight occurring at night because he does not fly frequently enough, at night, to maintain that currency on a continuous basis. Combining all military and civilian flight time, the author has logged over 2,000 hours, 240 of which have been at night.

Importance of the study

It is already well-known in the GA community that the accident rate at night in instrument meteorological conditions (IMC) is significantly higher than the overall accident rate (Landsberg, 1995). However, this does not necessarily address several key areas of concern:

- a) fatal accident rates, specifically.
- b) analysis of *all* night fatal accidents, which includes IMC and visual meteorological conditions (VMC).
- c) whether inflight encounter with weather is a more significant factor in night (versus day) fatal accidents.
- d) whether the pilots involved were instrument rated versus non-instrument rated.

This study sought to determine the percentage of fatal accidents which occurred at night, as compared to the percentage of night flight hours. It also addressed whether a significantly higher percentage of night fatal accidents involve inflight encounter with weather as the first occurrence (as compared to day fatal accidents). These relationships were evaluated by analyzing Federal Aviation Administration (FAA) and National Transportation Safety Board (NTSB) records for the years 1985 through 1994.

Definition of Terms

Aviation nomenclature is quite extensive and most nomenclature used in this study is contained in the Pilot/Controller Glossary in the Airman's Information Manual (AIM). The author assumes that the reader is familiar with this terminology. The following list contains terms which may not be in the AIM Glossary, as well as terms used by the NTSB for the purposes of accident data classification.

Aircraft Accident

"An occurrence incident to flight in which, as a result of the operation of an aircraft, any person (occupant or non-occupant) receives fatal or serious injury or any aircraft receives substantial damage" (Nall Report, 1996, p. 25).

Aircraft Accident, Fatal

For the purposes of this study, an accident resulting in one or more fatality occurring within 30 days of the mishap as the result of injuries sustained during the mishap.

Aircraft Category and Class

Aircraft *categories* refer to a broad classification of flying machines with similar characteristics. Airplanes, rotorcraft, gliders, and lighter-than-air are examples of different categories of aircraft. Single-engine, multi-engine, and sea are different *classes* of airplanes. GA encompasses all categories and classes of aircraft. This study will also consider all categories and classes of aircraft.

Federal Aviation Regulations (FAR)

Regulations governing the operation of U.S. registered aircraft and aircraft operating within the confines of the sovereign airspace of the USA. These regulations are contained in Title 14 of the Federal Code (14 CFR) and are divided into various parts.

First Occurrence

The first occurrence or event, in the accident sequence, without which the accident would not have likely occurred.

General Aviation

The portion of civil aviation not involved in scheduled airline or air-taxi/commercial operations. "General aviation (GA) provides both personal and business transportation and supports diverse activities, including recreation, law enforcement, forest fire fighting, freight transportation, air ambulance, and many other vital services" (Nall Report, 1996, p. 4).

Night

“...the period beginning 1 hour after sunset and ending 1 hour before sunrise (as published in the American Air Almanac). . .” (FAA, 1997, p. 44).

CHAPTER II

REVIEW OF RELEVANT LITERATURE AND RESEARCH

In order to understand the nature of night flying as well as to appreciate some of the contributing factors to night accidents, it is important to review some of the unique risks associated with night flying. It is also helpful to review how probable causes and first occurrences relate to aircraft accidents and to one another. In addition, this section will summarize the night training that a student pilot receives, currency requirements for the licensed pilot, and night related regulations. Finally, findings already available that relate to GA night accidents will be covered.

Risks Associated with Night Flying

Overview

Most of the risks associated with night flying are fairly well known and understood. Others are well documented, yet frequently pilots fail to consider them. The risks being discussed are people related, since the aircraft itself obviously does not care if it is flying with or without the benefit of sunlight. One of the problems is the increased risk that a night, off-airport landing poses. Chamberlain explained:

Simply stated, in the event of an off-airport precautionary [or emergency] landing there is a greater chance of injury at night because it is more difficult to find a good landing site in the dark. It is hard to land safely where you can't see the rocks and trees. (1996, p. 10)

A related issue is the difficulty in seeing weather systems, whether it be fog, rainshowers, or thunderstorms, along the route of flight. Many of these phenomena would be apparent, and therefore avoidable, during daylight visual flight rules (VFR) operations. While the vast majority of commercial carriers have onboard weather radar equipment to detect such weather systems, most GA aircraft do not (Chamberlain, 1996).

A question posed in a recent FLYING Magazine survey of 1,000 pilots was: What is the most stressful part of the flight for you? The response options were: a) takeoff and departure phase, b) approach and landing phase, or c) encountering bad weather during any part of the flight. Seventy-four percent of the private pilots and 78 % of the commercial pilots responded that encountering bad weather was the most stressful. The stress and associated consequences are inevitably more significant when the encounter with weather is unforeseen or unexpected, as is often the case at night (Collins, 1995).

Human Factors

Chamberlain goes on to describe some human factors issues which he perceives may be the greater risk. The human piloting the aircraft is a daytime creature and is not designed to function well at night. One's night vision is poorer than one's day vision and is subject to various nighttime induced illusions. Additionally, humans are more active during daylight hours and tend to slow down and are less alert when it is dark.

Another factor to be considered is the human tendency to manage everything by the clock, which can control a person to the point where they become a safety risk. "Our desire to get home on time at all costs is one example. Another example is the fact that many GA pilots flying at night are not professional pilots with duty and rest requirements and limitations" (Chamberlain, 1996, p. 10).

This is not to say that GA pilots are not good pilots; rather, in many cases, GA pilots flying themselves at night have worked a full workday and are flying either to return home after a business trip, or they are flying for personal reasons such as maintaining their night currency.

Chamberlain argues that the resulting fatigue from these realistic scenarios increases the likelihood that the pilot is not as sharp as possible. Therefore, pilot judgment may suffer and his or her reflexes are slowed. On top of all this, the pilot's need for oxygen at lower altitudes increases. These and many other physiological factors may combine to cause an accident that might not happen during the day (Chamberlain, 1996).

Physiological Factors

One of these physiological factors previously mentioned is the pilot's night vision. "It is important for the pilot to understand the construction of the human eye, since it is so constructed that to see effectively at night it must be used differently from the daytime" (Urquhart, 1996, p. 25).

The retina is made up of various layers of cells, among them the significant cells for vision: the rods and cones. There are more than seven million cones in each human eye, located close together in the very center of the retina. The rods are concentrated in a ring around the cones. The function of each is crucial, with the cones detecting colors, details, and distant objects, while the rods function when an object is in one's peripheral view. The rods detect objects, particularly moving ones, but do not provide detail or color, only shades of gray.

In the absence of daylight or bright moonlight, one's vision depends almost entirely upon the rods. The rods require about 30 minutes to become adjusted to darkness, at

which time they become nearly 100,000 times more sensitive to light than they are during daylight. The fact that the rods are distributed in a band around the cones makes “off center” viewing particularly important during night flight. During daylight, an object is best seen by looking directly at it. At night, however, a scanning procedure to permit “off center” viewing of the object is more effective.

It is also important for the pilot to maintain good physical condition. Smoking, the presence of carbon monoxide, hypoxia, Vitamin A deficiency, and the use of certain drugs adversely affect the eyes’ night vision capabilities.

Proper cockpit lighting is another critical factor in night vision. Dim red lighting has the least adverse effect on night vision, but severely distorts color. The tendency in recent years has been toward the use of diffused white or blue-white instrument lighting. Too much lighting, whatever the color, can greatly reduce the effectiveness of the rods.

Urquhart proposes, and this author agrees, that many aviators are completely uninformed about night vision and believe there is nothing to be learned about the subject. In actuality, good night vision requires an understanding of rods and cones as well as a disciplined approach to both scanning and cockpit lighting (Urquhart, 1996).

Spatial Disorientation

Related to the problems of night vision are a number of illusions which the AIM ranks among the most common factors contributing to fatal accidents. The AIM says the following illusions can cause spatial disorientation: the leans, vertigo, coriolis illusion, graveyard spin, graveyard spiral, somatogravic illusion, inversion illusion, elevator illusion, false horizon, and autokinesis.

While these illusions can occur in daylight or at night, they are particularly dangerous at night because of the decreased likelihood of having a discernible horizon. Most non-instrument rated pilots have had minimal exposure to flying solely with reference to instruments. This highlights the necessity of a discernible horizon for such a pilot because it is his or her primary reference for keeping the airplane upright.

A discussion of each of the various types of illusions is beyond the scope of this paper. However, it is important to note that they all contribute to spatial disorientation; a condition where the pilot does not know his or her aircraft attitude in terms of bank angle and/or pitch. This loss of awareness is a significant factor when studying night accidents (Chamberlain, 1996).

Techniques to Reduce Risk

So what can be done to combat potential night related accidents? Chamberlain suggests first realizing there is greater risk when flying at night and to incorporate as many of the following techniques as possible:

- a) have someone else on board to help keep you alert.
- b) schedule night proficiency flying on a non-working day so you can be well rested and have more time to prepare.
- c) raise your own personal safety minimums at night, such as higher weather requirements and more fuel.
- d) simply do not fly at night if you are tired (Chamberlain, 1996).

Probable Causes and First Occurrences

The following is a good working definition of accident probable cause(s):

Condition(s) or event(s), or the collective sequence of conditions or events, that

most probably caused the accident to occur. Had the condition(s) or event(s) been prevented, or had one or more conditions or events been omitted from the sequence, the accident would not have occurred. (Nall Report, 1994, p. 14)

Compared to probable cause, first occurrence is basically another method of classifying accidents. They are similar in that it can also be said of first occurrences that, without that first occurrence, the accident would not have likely transpired. A few examples of first occurrences are; loss of control, inflight collision with terrain/water, and inflight encounter with weather. In light of these examples, it is understandable that the inflight encounter with weather occurrence could lead to spatial disorientation and, subsequently, the loss of control occurrence. Naturally, for accident investigation and prevention purposes, the *first* occurrence is the one of most concern.

Many accidents having inflight encounter with weather as the first occurrence will also list *continued VFR flight into IMC* as the probable cause. From this, it is clear that probable cause and first occurrence have a definite relationship. However, they are not exactly the same. For example, while an accident may be ascribed multiple probable causes, there can be, by definition, only one first occurrence.

Because the available NTSB database tracks first occurrences (but not probable causes), first occurrences are addressed in this research project.

Night Training, Currency Requirements, and Regulations

Night Training--Private pilot

The FAR, Part 61, specifies that the applicant for a private pilot certificate must have logged instruction from an authorized flight instructor in certain pilot operations. In addition, the applicant's logbook must contain an endorsement by an authorized flight

instructor who has found him or her competent to perform each of those operations safely as a private pilot. One of the operations specified is *night flying, including takeoffs, landings, and VFR navigation*. Another, listed separately and without regard to day or night, is *controlling and maneuvering an airplane solely by reference to instruments*.

So far, there is obviously the intent to expose the student pilot to some night and instrument flying, but no real specifics as the extent of the training. Part 61 goes on to explain that, among the 20 hours of flight instruction required for an applicant for a private pilot certificate, applicants seeking night flying privileges must have at least three hours of instruction at night, including 10 takeoffs and landings. An applicant who does not meet this specific night flying requirement is issued a private pilot certificate bearing the limitation 'night flying prohibited'. This limitation may be removed if the holder of the certificate shows that he or she has met the requirement at a later time.

Night Experience--Commercial Pilot

An applicant for a commercial pilot certificate must hold an instrument rating or the commercial pilot certificate that is issued is endorsed with a limitation prohibiting the carriage of passengers for hire on cross-country flights of more than 50 nautical miles, *or at night*.

The commercial applicant must also meet a number of hour requirements, one of which is five hours of night flying, including at least 10 takeoffs and landings as sole manipulator of the controls.

Overall Experience--Instrument Rated Pilot

Although there are no night specific experience requirements for the instrument rating applicant, it is worth noting the training required for attaining the instrument rating,

especially when compared to the mere “introduction to instruments” that most non-instrument rated private pilots receive.

The hour requirements for the applicant for an instrument rating include, among other things, 40 hours of simulated or actual instrument time. Of these 40 hours, not more than 20 hours may be instrument instruction. In other words, a certain portion of the 40 hours must be without the benefit of an instructor. However, at least 15 hours of instrument flight instruction are required.

Night Currency Requirements

Regarding recent night flight experience, Part 61.57 states:

. . .no person may act as a pilot in command of an aircraft carrying passengers at night (the period beginning 1 hour after sunset and ending 1 hour before sunrise-as published in the American Air Almanac) unless, within the preceding 90 days, that person has made not fewer than three takeoffs and three landings to a full stop, at night, as the sole manipulator of the flight controls in the same category and class of aircraft. (FAA, 1997, p. 44)

This currency requirement applies whether the pilot holds a private pilot or commercial pilot certificate; is single-engine or multi-engine qualified; or is instrument rated or non-instrument rated.

Instrument Currency Requirements

Again, the instrument currency requirements are stated without regard to day or night but are still noteworthy. For most GA operations, no pilot may act as pilot in command under instrument flight rules (IFR) unless that pilot has, within the last six calendar months, logged at least six hours of instrument time, including at least six

instrument approaches under actual or simulated instrument conditions. If the above requirements are not met, the pilot may not serve as pilot in command under IFR until that pilot passes an instrument competency check given by an approved instructor or inspector.

Other Night Related Regulations

FAR Part 91 outlines a progression of instruments and equipment required for various flight conditions. For VFR day operations, the basic flight instruments (airspeed indicator, altimeter, and so forth) as well as various engine gauges are listed. For VFR night operations, all of the VFR day equipment is required plus:

- a) position lights.
- b) anticollision light system.
- c) one electric landing light, if the aircraft is operated for hire.
- d) adequate source of electrical energy for installed electrical and radio equipment.
- e) one spare set of fuses, accessible to the pilot in flight.

For IFR flight, day or night, some additional equipment is required. This includes, but is not limited to, a gyroscopic pitch and bank indicator (artificial horizon), a slip-skid indicator, and a gyroscopic direction indicator (directional gyro or equivalent) (FAA, 1997).

This progression of necessary equipment highlights the FAAs view that, as one progresses into night, and subsequently IFR, flying, those operations generally become increasingly demanding. Marsh summarizes the feelings of many aviation experts on the issue of GA currency requirements:

Meeting night currency requirements for carrying passengers is simple-too simple, some would say; three takeoffs and three landing to a full stop every 90 days, and you're done. There's no dual instruction required, no demonstration of handling emergencies, and no cross-country navigation. While the gremlins' specialty is burning out landing lights, they are also experts at creating foul weather and promoting poor decision making-'designer' gremlins, you might call them. Lack of currency can turn a starry night into a scary one. (1994, pp. 71-72)

Marsh recommends that, rather than buzzing around the pattern alone for 30 minutes to become current--as the regulations allow--pilots should periodically challenge themselves through dedicated night dual instruction (Marsh, 1994).

Night Accidents--Previous Findings

Richard Collins of FLYING Magazine frequently researches GA accidents and addresses accident prevention. In summarizing the Joseph T. Nall GA Safety Report (Nall Report) for 1993, Collins states:

When you fly makes a big difference, too. The accident rate in VFR conditions, day or night, is about the same and isn't too bad. The serious accident rate in daytime instrument meteorological condition (IMC) is twice as high as the VFR weather rate. The astounding number is the night IMC rate: It is, according to the report, eight times higher than the day VFR rate. . . .When you find one area-night IMC-that is so lethal to one type pilot (business and personal) but not all pilots (airline and cargo folk don't have the problem), then something is totally out of whack. I've said it before and I'll say it again: If you are going to fly at night, set your minimum weather, currency and proficiency standards many times higher than the

FAA's and include night instrument approaches in the practice if you fly IFR.

(Collins, 1994, pp. 14, 16)

Another way of viewing the 1993 data is presented by the Aircraft Owners and Pilots Association's (AOPA) Air Safety Foundation (ASF). They report that the total accident rate (not fatal accident rate) in nighttime IMC (21.47 accidents per 100,000 hours) is 270 % higher than the GA overall accident rate (8.79 accidents per 100,000 hours) (Landsberg, 1995).

Marsh explains some findings concerning the single greatest cause of night accidents:

Although engine failure at night is the main concern for most pilots, statistics from the ASF show the greater accident cause is *continued VFR flight into instrument conditions* [italics added]. The latest Joseph T. Nall General Aviation Safety Report from ASF rates the risk of a serious accident during night instrument weather conditions as 'very high'. 'Continued night VFR flight into instrument conditions is as close to suicide as you can get', says ASF Executive Director Bruce Landsberg. There was a total of 64 accidents in night instrument conditions during 1994. That may not seem like a high number, but it is spread over relatively few night flying hours, Landsberg said. (1994, p. 73)

Aside from engine failure, the next greatest concern for most pilots is the touchdown (Marsh, 1994). Successfully "finding the runway" at night can be difficult due to a number of factors. Failure to properly scan with the eyes, as previously mentioned, is one factor. Another is the infamous black hole approach. Generally, this refers to a night

approach situation where there are no ground lights or other visible detail short of the runway (as is almost always the case in over-water approaches).

Frequently there is a town, or other source of light, farther away (beyond the runway) and is the only light available to define the ground plane.

Many pilots will look for vertical guidance information in the angle that lies between the line of sight to the farthest visible light. . . and the nearest light. The pilot might descend into the terrain long before reaching the runway. (Haines & Flatau, 1992, p. 106)

How is a pilot to avoid the black hole illusion and its consequences? The primary step is to regularly look back inside the cockpit for instrument information. The pilot should scan altitude, vertical rate, airspeed, and distance to go and then mentally compare this information with the outside scene. If something does not look right, trust the instruments (Haines & Flatau, 1992).

Summary of Relevant Data

Concerning GA operations, the unique risks and more demanding nature of night flying, as compared to daylight flying, are well documented. Some would argue that more in-depth training and more stringent currency requirements are necessary in view of the peculiarities of night flying.

Relevant data in the subject area holds that there is a gross number of night *IMC* accidents. However, none of the sources found compare all night accidents with all day accidents. Nor do they specifically address fatal accident statistics. This study determined the percentage of fatal accidents which occurred at night, as compared to the percentage of night flight hours. It also addressed whether a significantly higher percentage of night

fatal accidents involve inflight encounter with weather as the first occurrence (as compared to day fatal accidents).

Statement of the Hypothesis

Research Hypothesis

In GA flying, there is a significantly disproportionate number of fatal accidents involving night flying as compared to night hours flown. Additionally, comparing day and night fatal accidents, a significantly higher percentage of night accidents involve inflight encounter with weather as the first occurrence.

Statistical Hypothesis

In GA flying, there is no statistical numerical difference between night and day fatal accidents, when compared with hours flown, at the $p < .05$ level of significance. Additionally, when comparing day and night, there is no significant difference in the percentage of fatal accidents involving inflight encounter with weather as the first occurrence, as measured at the $p < .05$ level of significance.

CHAPTER III

RESEARCH METHODOLOGY

Research Technique

This is a descriptive study which utilized correlational research in order to correlate and contrast accident data. A t-test for independent samples analysis was used to compare the percentage of GA fatal accidents occurring at night, to the percentage of GA hours flown at night. A second analysis compared the percentage of day fatal accidents having inflight encounter with weather as the first occurrence, with the same percentage for night fatal accidents.

Research Design

This study involved first determining, as accurately as possible, a division of GA hours flown into day and night categories. This was accomplished by utilizing FAA data covering a 10 year time frame; 1985 to 1994. For each year, the percentage of annual fatal accidents that occurred at night was then compared with the percentage of annual hours flown at night. The study also sought to identify if a significantly higher percentage of night fatal accidents involve inflight encounter with weather as the first occurrence (as compared to day fatal accidents).

Sources of Data

Pat Beardsley of the FAA's Research and Special Programs Office provided the breakdown of night versus day hours flown for the study period. The data containing

actual fatal accident numbers under various conditions (day versus night, instrument rated versus non-instrument, and so on) was obtained by direct inquiry of the NTSB database. This data was made available by Stan Smith, Chief of the Analysis and Data Division. Smith can be reached by phone at (202) 314-6550 between 8:00 AM and 4:30 PM Eastern Time, Monday through Friday, or via the Internet (smiths@ntsb.gov). Written inquiries may be directed to: Stan Smith (RE-50); NTSB; 490 L'Efant Plaza, S.W.; Washington, D.C. 20594-2000.

Reliability

By using the exact same methods and parameters for analyzing data from each of the 10 years, this study quantified accidents, *relative to hours flown*, with a high level of consistency.

Validity

The NTSB's database is widely held as the most complete and accurate source of information available for aircraft accidents occurring in the U.S. This study is valid only as it relates to night GA fatal accidents. It would not be valid, for example, to apply the results to night fatal accidents of airlines operating under FAR Part 121. Nor would it be valid to apply the results to night GA accidents overall (fatal and nonfatal).

Delimitations

This study only analyzed fatal accidents. The researcher desired to focus on only the most serious of accidents. This narrowing of scope also served to limit the database to a more manageable size.

The study is also limited to GA operations. Other aviation operations, such as corporate flights and the airlines were not included. These "other" operations are

generally conducted under rules that minimize or negate the difference between day and night flying (such as operating under IFR regardless of the weather and light conditions).

The study period, 1985-1994, is an obvious delimitation in that it does not cover every year in which GA night fatal accidents have occurred. Since the intent is to capture "the way things are", a relatively recent 10 year time frame was selected. During the study period, GA aircraft and instrumentation were, for the most part, comparable to today.

Limitations

A limitation of this study is the manner in which the NTSB maintains aviation accident data. This data is always subject to slight changes because the data for any particular year is not necessarily complete. In other words, if an investigation required several years to complete, that data would be added to the database on an ex post facto basis. Therefore, historical data is not truly static, although changes are so minor after the publication of the formal annual data report as to be inconsequential. The NTSB database is updated daily and is the most current source of information, although published reports lag by a considerable margin. The NTSB publishes data annually but, due to extensive investigations, the reports often take a considerable amount of time to prepare. The computerized database maintained by the NTSB contains data from 1983 through the present (Vaccaro, 1996).

Assumptions

One important assumption in this study is that the NTSB's database is the most complete and accurate source of information available for aircraft accidents occurring in the U.S. It is also assumed that either: a) the NTSB has reported on every GA fatal

accident that occurred during the study period or b) if not, that what they did report on is generally representative of all GA fatal accidents.

A second assumption is that the FAA-provided breakdown of GA hours flown into day and night categories is representative of the population at large. Flying hour data are estimated by the FAA using statistical forecasting techniques and data from the GA and Air Taxi Activity and Avionics Survey, distributed to a sample population of pilots each year.

Treatment of Data and Procedures

A t-test for independent samples analysis will be used to compare the percentage of GA fatal accidents occurring at night to the percentage of GA hours flown at night. A second analysis will compare the percentage of day fatal accidents having inflight encounter with weather as the first occurrence with the same percentage for night fatal accidents.

CHAPTER IV

RESULTS

Night Fatal Accidents versus Night Hours Flown

To compare GA night fatal accidents with GA night hours flown, a t-test for independent samples was applied. The percentage of GA fatal accidents occurring at night for the years 1985 through 1994 was treated as group one in the t-test analysis and is presented in Table 1.

Table 1

Percentage of GA Fatal Accidents Occurring at Night

YEAR	DAY FATAL ACCIDENTS	NIGHT FATAL ACCIDENTS	DAY + NIGHT FATAL ACCIDENTS	PERCENT OCCURRING AT NIGHT
1985	374	103	477	21.6
1986	349	108	457	23.6
1987	344	83	427	19.4
1988	335	90	425	21.2
1989	347	75	422	17.8
1990	348	83	431	19.3
1991	334	77	411	18.7
1992	336	86	422	20.4
1993	299	79	378	20.9
1994	316	77	393	19.6

For those same years, the percentage of GA hours flown at night is provided in Table 2. This latter percentage was treated as group two in the t-test analysis. The percentages from Tables 1 and 2 are compiled and presented for comparison in Table 3.

Table 2

Percentage of GA Hours Flown at Night

YEAR	DAY HOURS FLOWN	NIGHT HOURS FLOWN	DAY + NIGHT HOURS FLOWN	PERCENT FLOWN AT NIGHT
1985	29,104,539	4,958,417	34,062,956	14.6
1986	29,347,992	4,477,209	33,825,201	13.2
1987	28,610,406	4,109,906	32,720,312	12.6
1988	29,089,856	4,420,771	33,510,627	13.2
1989	26,560,114	5,354,090	31,914,204	16.8
1990	28,885,278	5,580,775	34,466,053	16.2
1991	17,194,092	2,581,724	19,775,816	13.1
1992	23,164,157	3,329,317	26,493,474	12.6
1993	18,735,931	2,514,979	21,250,910	11.8
1994	20,517,476	3,348,489	23,865,965	14.0

Table 3

Comparison of Night Fatal Accidents with Hours Flown at Night

YEAR	PERCENT FATAL ACCIDENTS AT NIGHT	PERCENT HOURS FLOWN AT NIGHT
1985	21.6	14.6
1986	23.6	13.2
1987	19.4	12.6
1988	21.2	13.2
1989	17.8	16.8
1990	19.3	16.2
1991	18.7	13.1
1992	20.4	12.6
1993	20.9	11.8
1994	19.6	14.0

Another way to view the data in Table 3 is to compute both day and night fatal accidents per 100,000 hours of exposure. This day/night breakdown is detailed in the Appendix. Using 1985 as an example, there were 1.29 day fatal accidents for every 100,000 day hours flown, whereas there were 2.08 night fatal accidents for every 100,000 night hours flown.

In order to identify if a significant difference exists between the two sets of data, the t-test was applied to the percentages in Table 3. The analysis indicated a significant difference between the data sets (at the $p < .05$ level of significance).

Table 4 contains the results of the t-test analysis applied to the percentage of fatal accidents occurring at night versus the percentage of hours flown at night. Table 4 indicates that the t-value for night fatal accidents is 8.78. This exceeds the t-value of 2.101 (18 degrees of freedom) required at the $p < .05$ level of significance.

Table 4

t-Test Results: Night Fatal Accidents

STATISTIC	VALUE
number of scores in group one	10
sum of scores in group one	202.50
mean of group one	20.25
sum of squared scores in group one	4125.47
sum of squares of group one	24.85
number of scores in group two	10
sum of scores in group two	138.10
mean of group two	13.81
sum of squared scores in group two	1930.69
sum of squares of group two	23.53
t-value	8.78
degrees of freedom	18

Inflight Encounter with Weather

A t-test for independent samples was also applied to identify if the inflight encounter with weather first occurrence was significantly more predominant at night than during the day. Table 5 depicts both the raw numbers and the percentage of day/night fatal accidents having inflight encounter with weather as the first occurrence. For example, considering 1985 data, 68 day fatal accidents had inflight encounter with weather as the first occurrence. Relative to all 374 day fatal accidents for that year (from Table 1), these 68 represent 18.2 % of that total. The same method was used to arrive at the night percentages.

Table 5

Fatal Accidents having Inflight Encounter with Weather as First Occurrence

YEAR	NUMBER, DAY	NUMBER, NIGHT	PERCENT, DAY	PERCENT, NIGHT
1985	68	37	18.2	35.9
1986	45	39	12.9	36.1
1987	56	24	16.3	28.9
1988	48	29	14.3	32.2
1989	52	26	15.0	34.7
1990	35	21	10.1	25.3
1991	36	16	10.8	20.8
1992	34	15	10.1	17.4
1993	27	19	9.0	24.1
1994	18	12	5.7	15.6

In the t-test analysis, the day percentage was treated as group one and the night percentage was treated as group two. The analysis indicated that there was a significant difference between the data sets (at the $p < .05$ level of significance).

Table 6 contains the results of the t-test analysis applied to the percentage of day/night fatal accidents with inflight encounter with weather as first occurrence. Table 6 indicates that the t-value is 5.52. This exceeds the t-value of 2.101 (18 degrees of freedom) required at the $p < .05$ level of significance.

Table 6

t-Test Results: Inflight Encounter with Weather

STATISTIC	VALUE
number of scores in group one	10
sum of scores in group one	122.40
mean of group one	12.24
sum of squared scores in group one	1626.98
sum of squares of group one	128.80
number of scores in group two	10
sum of scores in group two	271.00
mean of group two	27.10
sum of squared scores in group two	7867.82
sum of squares of group two	523.72
t-value	5.52
degrees of freedom	18

CHAPTER V

DISCUSSION

Night Fatal Accidents versus Night Hours Flown

The t-test analysis performed in the previous chapter indicates that there is a statistical difference (assuming $p < .05$ level of significance) between the percentage of GA fatal accidents occurring at night and the percentage of hours flown at night. Combining the yearly data for each of the ten years in the study period, the mean percentage of fatal accidents which occurred at night was 20.25. For the same period, the mean percentage of hours flown at night was 13.81. One would expect this fairly substantial spread when averaging all the yearly data together, given the t-value presented earlier for this relationship. However, it is also worth noting that every year in the ten year study period had a higher percentage of fatal accidents occurring at night as compared to the percentage of hours flown at night. The smallest difference was noted in 1989, with 17.8 % of the fatal accidents occurring at night and 16.8 % of the hours flown at night. Nineteen-eighty-six represented the largest difference, with 23.6 % of the fatal accidents occurring at night, and 13.2 % of the hours flown at night.

Previous research and literature has established that there are a disproportionate number of night IMC accidents. This study indicates that there is also a disproportionate number of night overall (IMC and VMC) fatal accidents. There can be no denying that,

all other things being equal, night GA flying claims more than its fair share of fatal accidents.

Inflight Encounter with Weather

The t-test analysis performed in the previous chapter indicates that there is also a statistical difference (assuming $p < .05$ level of significance) between the percentage of GA day and night fatal accidents having inflight encounter with weather as the first occurrence. Combining the yearly data for each of the ten years in the study period, the mean percentage of day fatal accidents with this particular first occurrence was 12.24. For the same period, the mean percentage of night fatal accidents with this particular first occurrence was 27.10. In each of the ten years, a lower percentage of day fatal accidents involved inflight encounter with weather, as compared to the percentage of night fatal accidents involving inflight encounter with weather. The smallest difference was noted in 1992, with 10.1 % and 17.4 %, respectively. Nineteen-eighty-six represented the largest difference, with 12.9 % and 36.1 %, respectively.

Considering the FLYING Magazine survey quoted earlier, it is understandable that roughly three-fourths of the pilots responded that encountering bad weather while inflight was one of the most stressful challenges they might face. When a GA accident involves inflight encounter with weather, it is undeniable that the risk is significantly higher if flying at night.

CHAPTER VI

CONCLUSIONS

Night Fatal Accidents versus Night Hours Flown

In GA flying, there is a statistically significant difference between the percentage of fatal accidents occurring at night and the percentage of hours flown at night (at the $p < .05$ level of significance). Therefore, the research hypothesis is supported and the null hypothesis rejected.

It would be logical that a disproportionate number of fatal accidents occur at night. For example, consider an aircraft malfunction that demands an off-airport precautionary or emergency landing. Even an emergency landing is not, in and of itself, considered an accident. Contrasting night and day, this scenario at night offers the pilot a much smaller chance of being able to visually identify a suitable landing zone. All other things being equal, a night forced landing is more likely to result in a fatal accident than a day forced landing.

Inflight Encounter with Weather

Considering GA fatal accidents, there is a statistically significant difference between the percentage of night accidents involving inflight encounter with weather, and the percentage of day accidents involving inflight encounter with weather, at the $p < .05$ level of significance. Therefore, the research hypothesis is supported and the null hypothesis rejected.

Again, contrasting day and night, the inflight encounter with weather occurrence also poses some unique problems at night. Night flying presents a significantly degraded capability to simply see, and therefore avoid, the weather. This includes not only dangerous weather systems such as thunderstorms, but also fair weather clouds or fog that can easily lead to disorientation, especially for the non-instrument rated pilot. Therefore, what is generally easy to avoid during the day can--and frequently does--become a problem at night. This is especially true for pilots who are not properly equipped or trained, and are caught off guard by inadvertently entering the weather. For many such pilots, the disorientation that is likely to result frequently leads to loss of aircraft control and a fatal accident.

Additional Findings--Pilot Qualifications

Until now the issue of pilot qualifications, as it relates to fatal accidents, has not been addressed, even though it is an area where one would expect to find a relationship. Unfortunately, it is difficult at this time to do valid, conclusive research on the issue of whether non-instrument rated pilots are more at risk when night flying, as compared to instrument rated pilots. There is currently no exposure data for night hours flown, which is quantified by pilot qualification (instrument rating, or lack thereof, in this case).

Table 7 depicts both the raw numbers and the percentage of day/night fatal accidents having a non-instrument rated pilot acting as the pilot in command (PIC). For example, considering 1985 data, 212 day fatal accidents had a non-instrument rated pilot acting as PIC. Relative to all 374 day fatal accidents for that year (from Table 1), these 212 represent 56.7 % of that total. The same method was used to arrive at the night percentages.

Table 7

Fatal Accidents with a Non-Instrument Rated Pilot as PIC

YEAR	NUMBER, DAY	NUMBER, NIGHT	PERCENT, DAY	PERCENT, NIGHT
1985	212	41	56.7	39.8
1986	205	58	58.7	53.7
1987	185	35	53.8	42.2
1988	178	38	53.1	42.2
1989	179	43	51.6	57.3
1990	181	42	52.0	50.6
1991	167	37	50.0	48.1
1992	153	37	45.5	43.0
1993	145	23	48.5	29.1
1994	144	28	45.6	36.4

Considering raw numbers only (no exposure data), Table 7 consistently indicates that a higher percentage of day fatal accidents involved non-instrument rated pilots than did night fatal accidents. Over the ten year study period, on average, 51.6 % of all day fatal accidents involved non-instrument rated pilots while 44.2 % of all night fatal accidents involved non-instrument rated pilots.

One possible--and perhaps the most likely--explanation of the percentages in Table 7 is that non-instrument rated pilots simply do not fly as much at night. It could be argued that many GA pilots understand the unique risks of night flying, and that non-instrument rated pilots have their flying concentrated largely during daylight hours. If valid exposure data becomes available, a complete analysis on this issue would be possible.

If exposure data were available and were factored into the analysis, this researcher expects just the opposite would prove true; a higher percentage of night fatal accidents having non-instrument rated pilots, as compared to the day percentage. In other words, it

is anticipated that analysis which included exposure data would reveal non-instrument rated pilots as particularly susceptible to fatal accidents at night. This expectation is due, in large part, to an understanding of the similarities between night flying and flying in IMC. For example, a lack of a discernible horizon, as previously mentioned, is frequently common to both night and IMC flying. These and other similarities would seemingly make night flying all the more risky for a non-instrument rate pilot.

CHAPTER VII

RECOMMENDATIONS

Reducing Night Fatal Accidents

Many suggestions have been made with the goal of reducing overall night accidents. Naturally, those same recommendations can be applied to also help reduce the disproportionate number of night fatal accidents. However, some are particularly worth being expounded upon and/or modified.

Pilots in many other countries must have an instrument rating in order to fly at night. If an individual is going to fly frequently at night, this author strongly suggests investing the time and money to obtain an instrument rating. This research has shown that inflight encounter with weather claims a significantly higher percentage of night fatal accidents (compared to day). It follows that an instrument rating is a highly valuable qualification which better prepares one for inflight encounter with weather, especially at night.

This author also holds that the FAA minimum night currency requirements are exactly that; minimums. Government agencies, such as the FAA, can not be expected to implement and enforce the perfect set of requirements for each and every pilot. In addition to the minimums, the night flying pilot must take it upon him or herself to tailor their own training and currency requirements. If an instrument rating is not feasible, for whatever reason, practice basic hood work and unusual attitudes recoveries often with

a qualified instructor. Also, consider accomplishing your next biennial flight review at night.

Area for Further Study

Further study in the area of pilot qualifications (specifically instrument rated versus non-instrument rated), as it relates to night fatal accidents, would be of great benefit to the GA community. As previously explained, the limiting factor at the time of this research was the exposure data. The exposure data needed is night hours flown, quantified by pilot qualification (instrument rating, or lack thereof, in this case). If this information becomes available, this relationship should be re-examined to identify if, in fact, a higher percentage of night fatal accidents involve non-instrument rated pilots than day fatal accidents.

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APPENDIX

COMPARISON OF DAY/NIGHT FATAL ACCIDENTS (PER 100,000 HOURS)

YEAR	DAY	NIGHT
1985	1.29	2.08
1986	1.19	2.41
1987	1.20	2.02
1988	1.15	2.04
1989	1.31	1.40
1990	1.20	1.49
1991	1.94	2.98
1992	1.45	2.58
1993	1.60	3.14
1994	1.54	2.30